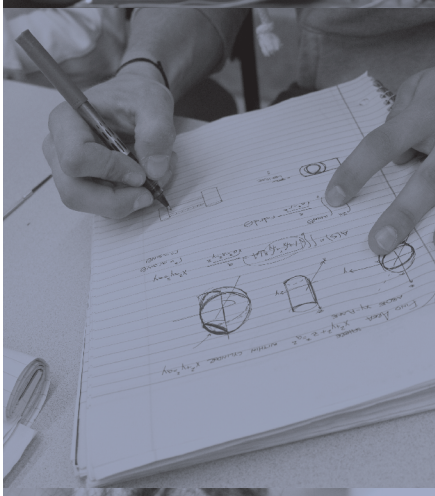
CHAPTER 6

BUILD A FIRM FOUNDATION

Managing Project Knowledge Efficiently and Effectively

Jon Jeffryes, University of Minnesota



Learning Objectives

So that you can guide student design teams on effective strategies to plan and manage information and knowledge collection critical to their project, upon reading this chapter you should be able to

- Describe the major information literacy concepts critical to successful knowledge management in a student team design project
- Identify common problems student teams have in developing, implementing, and maintaining an effective and efficient knowledge management plan and strategies to overcome these
- Describe the pros and cons of various computer-based tools, including citation management systems, to use as part of a successful knowledge management plan

INTRODUCTION

Before giving a design brief to student teams, instructors generally have them engage in some team organization activities, such as determining roles and developing a shared understanding of responsibility and accountability. One of the organizing activities frequently neglected, however, is determining how students will manage the information they gather and the knowledge they generate so that the whole team benefits. If they do discuss it, students may only go as far as saying they will set up a shared folder on Dropbox or Google Drive to hold their work. However, even if students have thought about a platform, they typically haven't thought about a process for organizing or communicating new information on that platform. Just as piling heaps of papers on one's desk doesn't constitute an effective organizing solution, especially for others trying to find a particular paper in one's filing system, dumping files into a shared folder likewise can lead to much confusion and inefficiency for the team.

Managing information and team knowledge are keys to the success of any design project. In 1986, the world witnessed one of the most dramatic and tragic design failures in modern history when the space shuttle *Challenger* exploded shortly after takeoff, killing all seven of its crew members. After a lengthy review, investigators found that the tragedy did not stem from a lack of information or bad data, but rather "failures in communication . . . based on incomplete and sometimes misleading information" (Presidential Commission on the Space Shuttle Challenger Accident, 1986).

As the *Challenger* explosion showed only too tragically, a well thought out plan for storing and communicating the information that each team member accrues during the course of a design project is necessary for a successful team project. This extends to the new knowledge generated by the team during the course of their project. As well as helping to avoid design failures, a thorough knowledge management plan can expedite the work of the team, making it more efficient and effective, and save time for all team members throughout the design process.

Knowledge management can most succinctly be defined as "the management of knowledge workers as well as the information they deal with" (Statt, 2004, p. 81). Kraaijenbrink and Wijnhoven (2006) expand that description, stating that "as an academic field, knowledge management has concentrated on the creation, storage, retrieval, transfer, and applications of knowledge within organizations" (p. 180). The literature on knowledge management explores further complexities (see Bredillet, 2004, for a nice introduction), but for the purposes of this chapter we will explore the topic using these more practical definitions focusing on the way information is managed throughout an organization, in this case an engineering student design team.

COMMON CHALLENGES FOR STUDENTS

The most difficult challenges design teams encounter in setting up a robust information management plan are motivation and time. Sitting down to have a conversation about how to share information and exchange knowledge is probably the least exciting part of a design project. Students will be keen to jump right into their first opportunities to practically ap-

ply all the technical skills they've been amassing during their college experience without considering future issues such as information management. Also, to make a thorough plan will take a considerable amount of time. For students with a full slate of classes and other activities, making the time up front to formulate a plan tends to be a lower priority (even with the promise of long-term time savings). To ensure the inclusion of this step, modeling sound design practice, the instructor should include it as the focus of a classroom session and make a formal, well-documented plan a graded deliverable of the project. To guarantee that students take the time to comply with the plan throughout the design process, each design team should designate a member with the responsibility of monitoring the information sharing in the role of an information manager.

INFORMATION LITERACY AND KNOWLEDGE MANAGEMENT

In their discussion of knowledge management, Kraaijenbrink and Wijnhoven (2006) describe a process of knowledge integration, made up "of three stages—identification, acquisition, and utilization of external knowledge" (p. 180). This process makes the most sense for the integration of information literacy skills. Returning to the facets of information literacy outlined in Chapter 2, this process maps nicely to the facets of locating information and evaluating information. Using Kuhlthau's (2004) Information Search Process, this step of the engineering design process would fall under the collection stage.

As outlined in Chapter 4, the introduction of information management occurs early in the Information-Rich Engineering Design (I-RED) model as the activity "organize the team." Introduction of these concepts at the beginning of the design process will prepare the team for success. This foundational skill sets the direction for the entire design project and needs to be addressed throughout the design process and over the design iterations. Engineering librarians will focus instructional efforts on the organization and communication of information gathered during the design process in literature reviews, collection of prior art, and searches for relevant standards and regulations that may impact the engineering design. The instructors can then correlate these practices to other steps such as experimental data management and collecting stakeholder feedback.

The connection between information literacy and knowledge management has been examined by Singh (2008), who found that "IL [information literacy] facilitates sense-making and reduction of vast quantities of information into fundamental patterns into a given context. That is also the heart of the matter in knowledge management" (p. 14).

O'Sullivan (2002) also examined the connection between information literacy and knowledge management and found that even when the corporate world does not use the terminology employed by their library counterparts, they do value the skill set required by both information literacy and knowledge management as integral to success in the workplace. Singh (2008) reinforces the importance of information literacy, placing it at the foundation of knowledge management. Engineering students may not engage intentionally with information literacy at this stage of their engineering design experience, but often the skills they are beginning to employ fall into this skill set. The engineering librarian can bring more

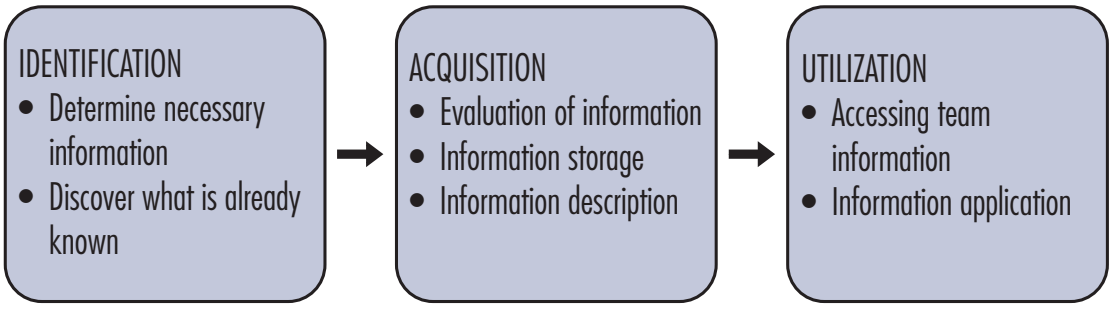


FIGURE 6.1 Information literacy within knowledge integration. (Modified from Kraaijenbrink & Wijnhoven, 2006.)

explicit understanding of these skills and their benefits into this early portion of the design process, setting the foundation for an information-enriched design process.

INTEGRATING INFORMATION LITERACY

Figure 6.1 incorporates information literacy into Kraaijenbrink and Wijnhoven's (2005) conception of knowledge integration.

For the purposes of an engineering design project this process is linear, but it will repeat throughout the design as students enter different stages of their project. Students follow the process outlined in Figure 6.1 while conducting their search for existing information in a literature review, and then start the process over when they start generating their own information in the experimental stage.

To establish good practices, a session on information management should occur early in the design project and focus on how the team plans to manage and communicate the process listed in Figure 6.1. Since the early stages of design include identifying relevant information that already exists, the focus of the illustration uses a literature search as its example. Citation management software provides a means of managing the information acquired during this stage of the design process.

CITATION MANAGEMENT

Citation management software provides an intuitive point of entry to integrate information literacy skills into the information management portion of engineering design. The software allows students to collaborate in the collection and organization of citations and subsequently output those citations into formatted bibliographies and in-text citations (see Box 6.1).

Childress (2011) has previously discussed the role of citation management software in library instruction. This software often falls in engineering librarians' wheelhouse because of their expertise in using scholarly citations, or because the library finances access to the tool(s). Librarians can exploit their mastery of these tools to simultaneously insert information literacy skills into the early stages of a design class and lay the foundation for the use of best practices in information management throughout the engineering design process.

Students easily recognize the value of citation management software for their course work and work flows. It can save students time

BOX 6.1

Citation Management Tools

EndNote
Fee-based citation management software. Downloads directly to the user's hard drive. Syncing and collaboration are available through EndNote Web.

Mendeley
Basic edition is free to download to the user's hard drive. Allows for online syncing and collaboration with groups. Basic edition limits number of groups as well as number of collaborators.

RefWorks
Fee-based citation management software that is entirely cloud based. With institutional subscription, students can have multiple accounts, allowing design teams to create a shared account.

Zotero
Free download is available online. Can be installed as Firefox plug-in or as a standalone program on the user's hard drive. Allows for online syncing and collaboration with groups at no additional cost.

and prevent instructors from puzzling through incomplete or poorly formatted citations. These time-saving aspects capture a classroom's attention and open the door for receptivity to information literacy skills. Duong (2010) has written specifically of the value of science librarians using Zotero in an outreach effort.

Citation management software can be divided into two major forms: fee-based and freeware. The fee-based citation managers (such as RefWorks and EndNote) are only available through institutional site licenses or personal purchases. Freeware programs (such as Zotero and Mendeley) provide a free basic software package and then charge for added functionality, such as extended cloud-based storage space and large group collaboration functionality. The engineering librarian and design instructor can determine which tool to incorporate into the class, but the evaluation and ultimate decision making can also be incorporated as a piece of the instruction itself—the engineering librarian providing students with the strengths and weaknesses of each tool and letting them critically engage with the information and decide which program will work for their individual group. Regardless of the type of software ultimately selected, most citation managers facilitate collaboration and organization through the creation of groups (sometimes also referred to as folders or libraries depending on the particular software—all the different terms provide the same type of functionality).

IN THE CLASSROOM

Ideally, citation management is introduced as part of an integrated, intentional information gathering process. Instruction starts with an introduction to the knowledge integration process outlined in Figure 6.1 and provides an overview of the different types of literature available and relevant to engineering design, as well as the tools available to locate this information. (More details on the different kinds and purposes of technical literature are covered in the following chapters.) The instructor, often an engineering librarian, provides a short lecture at the beginning of the classroom session, but this instruction might be covered in earlier course work or given as a pre-class video tutorial. The introductory content describes the development of a literature review strategy at the outset of the project and includes an offer of consultative services from the engineering librarian to the group for further, personalized guidance on which information resources might work well for their project.

After students are familiar with the variety of information types available, the instructor introduces the mechanics of the citation management software (in this example, the instructor and engineering librarian choose one citation manager that the entire class will use). This introduction provides a brief, general explanation of the functionality that the software offers and covers the mechanics of importing citations from indexing databases into a collaborative citation management group. The interaction between database and citation management software differs from database to database. This fact, often frustrating to the user, provides the engineering librarian the opportunity to showcase multiple information sources to the students. In discussing the steps necessary to retrieve citations from the article database, the instructor can also point out the differences in the citations that result from searching multiple information resources for articles on the same topic. These demonstrations also illustrate how word choice impacts results—modeling an ideal information-literate process.

An active learning exercise follows this short introduction and demonstration. Students are directed to work in their design teams to create a list of the types of literature they want to explore and the resources they plan to search. They will start to create a literature review plan, assigning individuals to particular resources and setting a deadline for completion. At the end of the discussion each team sets up a citation manager account and practices getting at least one citation into their library. At the end of the exercise, the instructor pulls the class together and connects the work they have just completed to the "Identification" stage of knowledge integration outlined in Figure 6.1.

Now the students have an account started and at least one citation included in their library. The instructor moves the presentation along to the collaborative use of descriptive tags and "Notes" fields of the citation record. These descriptors can be informative (i.e., where the design student located the information) or evaluative (i.e., the relevancy of the article to their project). These features of citation management software foster communication among the group members. The engineering librarian models effective practices—such as creating an article ranking terminology, noting who added or read a citation, and documenting the resource searched and the terms used to find the information—but ultimately the individual design teams determine their own unique methodology to employ these features.

The engineering librarian stresses the importance of agreeing on a standard descriptive practice early in the design process and employing it uniformly throughout the project. Following the routine ensures the most efficient use of student time, reducing the chance of duplication of work for the entire design team. This practice also illustrates the iterative nature of the research process. At the end of the process the design students will see that multiple search terms, employed in various information resources, were necessary for a comprehensive review of the current state of their design topic. These descriptors will also track the iterative nature of the design process itself, providing a record for the different approaches the team takes in regard to their design problem.

As mentioned, the notes and tags feature of the citation management software can also be used in the critical evaluation of information resources. A tagging structure based on the relevance and quality of the information included in the corresponding citation helps the whole design team quickly identify the best resources for their project. It also demonstrates that not all information is created equal and that every

resource must be read with a discerning eye. The tagging process also fosters critical dialogue when disagreements arise on the qualitative values noted. The notes feature can also be used to highlight particular portions of an article that are especially relevant to the research project (e.g., "look over pp. 20–22—skip the rest"). Once again the selling point to students will be that they are saving time for their group and increasing their efficiency, but at the same time the librarian advocates a critical engagement with every text and reaffirms that not everyone must read every article from abstract to bibliography.

At this point, the engineering librarian facilitates another learning activity. Students reconvene in their groups and discuss a standard descriptive practice to be used in the information management of their literature review. After the group discussion, students report out to the entire class for comment in order to facilitate peer learning. The instructor connects the work completed in the activity to the development of the "Acquisition" stage of knowledge integration outlined in Figure 6.1.

Following this discussion, the engineering librarian demonstrates the feature of the citation management software that automatically generates formatted bibliographies. This feature often captures the students' attention and demonstrates a concrete benefit that will result from their use of the citation manager. The bibliography-creation functionality can play an important role in the ethical use of information as well as in communicating with stakeholders about the team's progress. The instructor connects the demonstration to the "Utilization" stage of knowledge integration outlined in Figure 6.1.

Along with providing the design groups with efficiency-enhancing tools and introducing (or reinforcing) information literacy concepts, this session also models best practices in communication and transparency of process that should be employed throughout the entire information management process of the design project, including experimental methods, test findings, stakeholder feedback, and so forth. At the end of the session the course instructor brings the students' attention back to the knowledge integration model and discusses how they will want to come up with a standardized plan for managing their information at all stages of their design work. Just as they have developed procedures for sharing their literature resources, students will also need to make an agreed upon method for sharing the information they gather from all the different aspects of their design work. The session demonstrates how open communication and codified standard procedures provide the most efficient experience in team-based design work.

EVALUATION OF INTERVENTIONS

The active learning session outlined in the previous section provides multiple opportunities for the instructor to check in and provide formative assessment to ensure that students understand the content covered in the classroom session. As an assignment following this class session, students should be asked to submit a formal information management strategy for review as a deliverable of their project. In reviewing the plan the instructor and librarian will want to ensure that this strategy includes all three steps of the knowledge integration outlined previously. A rubric of all the details the instructor would like to see in the finalized plan (see Table 6.1) will help with consistent evaluation. If key components are missing, the instructor or librarian can provide point-of-need

TABLE 6.1 *Example Assessment Rubric for Knowledge Management Plan*

	Level of Achievement		
Criteria	**Poor**	**Satisfactory**	**Exemplary**
Identification Determining necessary information Discovering what is already known	Prepared limited list of applicable literature to search	Prepared broad list of applicable literature the team plans to search for their literature review Prepared list of possible information sources to locate information	Prepared a comprehensive list of applicable literature the team plans to search for their literature review Prepared a complementary list of information resources they plan to use in locating relevant information Created a plan to centrally record information that they learn they will need to create for themselves in the experimental phase
Acquisition Evaluating information Storing information Describing information	Created a shared citation manager account	Created shared citation manager account Created a plan to record the relevancy of individual information resources Created a plan to record how and where information was located	Created a shared citation manager account Created a description of a defined evaluation system to note the relevancy of information resources Created a detailed plan to note how and when information was located providing all the information to include
Utilization Locating team information Applying information	No plan created for adding new information outside of the literature review	Created a plan to store information created throughout the design process	Created a detailed plan to store information created throughout the design process, including storage location, file naming convention, etc.

assistance to individual teams to revise and strengthen their plans.

For longer-term assessment to guarantee that the instruction impacts the students' behavior and work processes, the most effective assessment technique is to add the instructor and librarian to each design team's collaborative citation manager group. The instructor and librarian can then periodically check each group's progress and provide formative assessment throughout the entire design process. The instructor and engineering librarian can monitor rates of adoption of the techniques outlined as well as make just-in-time suggestions for improvement to each group's methodology. This approach also allows the engineering librarian to learn what information-seeking skills might need further development and provide additional instructional interventions at the point of need.

The viability of this method of assessment would depend on the size of the design classes and the overall workload of the engineering librarian. (An engineering librarian supporting multiple departments' design classes at a large research university would quickly find him- or herself overwhelmed.) Along with the volume of groups requiring observation, this method of assessment would require supervision over the project's entire life span.

A less time-intensive assessment process would be to check in with each group in a more informal manner, via e-mail or by dropping in on a design team meeting, to learn where they've searched, what they've found, and how they are storing and sharing their information and to discover any outstanding information needs they still possess. For both of these longer-term assessments, conducted throughout the project's life cycle, the information management plan produced by the student groups would serve as a gauge for assessing success.

Another, less direct, way to assess the impact of the instruction on student behavior would be to send out a survey at the end of the design project asking students to share how they managed their information. This assessment method, although less of a time burden, relies on student memory and does not provide an opportunity to intervene and augment student behavior as it unfolds.

EXPANDING THE SKILL SET

As previously mentioned, the best practices of information management laid out in the citation management exercise—having an agreed upon process for adding information, critically assessing the information gathered, and the importance of transparency and strong communication—can be expanded throughout the design process. Information management is integral in collecting data from experimental models, gathering stakeholder feedback, and reporting out findings to stakeholders.

Because the underlying skills are the same, the example featuring citation managers outlined earlier could be supplemented or repeated with a similar exercise using other collaborative resources. The central idea, using a tool that will eventually save students' time to capture their attention and ensure buy-in, remains the same. Similar to the example provided earlier, the instructor provides information on the basics of knowledge integration (and possibly project management documentation) and then has the teams apply it to their own beginning work plan. Instead of using citation management software, students could engage with a variety of software programs available to them for collaboration (Google Drive, OpenOffice, OpenProj, SharePoint, etc.). The same basic outline described previously for the citation managers would work here as well, with the instructor imparting the best practices of information management in examples and demonstrations of each tool before having the class experiment and report back on which features worked or were lacking in the different tools.

The same approach can also be applied to the creation of a data management plan to identify, acquire, and utilize the information created by the student groups. This reinforcement provides valuable scaffolding for the students, repeating important core concepts in information management practice. It also allows the instructor to go deeper into the importance of keeping good records of the information that the teams create, and how

the management of those findings may prove important in other aspects of the design phase and ultimate manufacture.

Similar assessment strategies are appropriate when applying information management techniques to other portions of the design process. Using the information management plan created to conduct their literature review as a model provides students with a clearer understanding of the information management components of a data management plan and other future documentation.

SUMMARY

Information gathering and management occurs throughout the engineering design process, including searching the engineering literature, recording experimental data, and communicating with teammates and stakeholders, but it is vital for the design team to address this topic early in the design process to situate the team for maximal efficiency and ultimate success. Having students coordinate and collaborate on searches of the engineering literature for examples of prior art, current research in the area, and standards and regulations lends itself to the integration of information literacy skills into the information management process. Citation management software opens the door to an engineering design class's interest, with its promise of time savings and reduction in the duplication of work, to introduce information-literate management techniques. The successful use of these tools to employ information-literate information management practices illustrates a model of general information management techniques that will inform the students' understanding of other aspects of data gathering and management in the team's design process.

SELECTED EXERCISES

Exercise 6.1

Break students into their design teams and have them create a shared citation manager account. Instruct them to brainstorm places to look for literature on their design topic, find at least three citations, and practice importing them into their shared account. Once students have some citations loaded, have them devise a plan for organizing their citations within the citation manager's structures (i.e., determine what types of groups or folders they want to create to organize their citations). Also have the students discuss how they will evaluate and communicate about the citations they add using the tags or notes features. After students have conceived a plan, reconvene the larger group and have the different teams share their plan and allow their classmates to provide feedback.

Exercise 6.2

In their design groups, have the students come up with a shared space to save other pieces of information they plan to gather during their design project (e.g., Google Drive, Dropbox). Have students devise a folder structure and file naming conventions to make the retrieval of their created information intuitive and efficient. After students have devised a draft, have them share their organization plans with the larger class.

ACKNOWLEDGMENTS

The ideas represented in this chapter have evolved out of the development of a workshop that I created in collaboration with my

colleague, Jody Kempf, Instruction Coordinator for the Science & Engineering Library at the University of Minnesota, Twin Cities, and the work I did adapting that workshop for in-class integration for a mechanical engineering design class, partnering with faculty member Dr. Susan Mantell.

REFERENCES

Bredillet, C. (2004). Projects: Learning at the edge of organization. In P. W. G. Morris & J. K. Pinto (Eds.), *The Wiley guide to managing projects*. Hoboken, NJ: John Wiley & Sons, Inc. (pp. 1112–1136).

Childress, D. (2011). Citation tools in academic libraries: Best practices for reference and instruction. *Reference & User Services Quarterly*. *51*(2), 53–62. http://dx.doi.org/10.5860/rusq.51n2.143

Duong, K. (2010). Rolling out Zotero across campus as a part of a science librarian's outreach efforts. *Science & Technology Libraries*, *29*(4), 315–324. http://dx.doi.org/10.1080/0194262X.2010.523309

Kraaijenbrink, J., & Wijnhoven, F. (2006). External knowledge integration. In D. Schwartz (Ed.), *Encyclopedia of knowledge management*. Hershey, PA: IGI Global, pp. 180–187. http://dx.doi.org/10.4018/978-1-59140-573-3.ch024

Kuhlthau, C. C. (2004).*Seeking meaning: A process approach to library and information services* (2nd ed.). Westport, CT: Libraries Unlimited.

O'Sullivan, C. (2002). Is information literacy relevant in the real world? *Reference Services Review*, *30*(1), 7–14. http://dx.doi.org/10.1108/00907320210416492

Presidential Commission on the Space Shuttle Challenger Accident (1986). *Report of the Presidential Commission on the Space Shuttle Challenger Accident. Chapter V: The contributing cause of the accident*. Retrieved from http://history.nasa.gov/rogersrep/v1ch5.htm

Singh, J. (2008). Sense-making: Information literacy for lifelong learning and knowledge management. *DESIDOC Journal of Library & Information Technology*, *28*(2), 13–17.

Statt, D. A. (2004). *The Routledge dictionary of business management* (3rd ed.). London: Routledge.